

SEISMIC VULNERABILITY EVALUATION GUIDELINE FOR PRIVATE AND PUBLIC BUILDINGS

Part II: Post Disaster Damage Assessment



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Table of Contents

1. Introduction	1
1.1 Purpose.....	1
1.2 Basis and Scope	1
2. Damage Assessment Flow-chart	2
3. Rapid Evaluation	3
3.1 Visual Inspection	3
3.1.1 Equipment Needed.....	3
3.1.2 Assessment Work.....	4
3.1.3 Personal Qualification.....	4
3.1.4 Limitations	4
3.2 Evaluation and Certification	6
3.2.1 Inspected	7
3.2.2 Limited Entry of Restricted Use	8
3.2.3 Unsafe	9
4. Detail Evaluation	10
4.1 Understanding the Characteristics of Damaging Earthquake	10
4.2 Review of Existing Building Data	10
4.3 Assessing the Consequences of the Damaging Earthquake	10
4.4 Assessing Pre-existing Conditions.....	11
4.5 Survey the Building from Outside	11
4.6 Examine the site for Geotechnical Hazards	12
4.7 Inspect the structural system from inside the building.....	12
4.8 Conduct Test	12
4.8.1 Sounding Test	12
4.8.2 Rebound Hammer Test	13
4.8.3 Rebar Detection Test.....	15

4.8.4	In-Situ Testing In-Place Shear	16
4.9	Safety Evaluation	18
4.10	Identification of Damage Levels.....	18
5.	References	19
	ANNEXES	20
	Examples of Rapid Evaluation.....	20
	Examples of Detailed Evaluated Buildings.....	22

1. INTRODUCTION

1.1 Purpose

The purpose of this document is to provide practical criteria and guidance for evaluating earthquake *damage* to buildings with primary lateral-force-resisting systems consisting of reinforced concrete frame and masonry buildings which are prevalent in Nepal. The procedures in this manual are intended to characterize the observed damage caused by the earthquake in terms of the loss in building performance capability. The intended users of this document are primarily practicing engineers with experience in concrete and masonry design and construction with basic understanding of earthquake resistant design and construction. Information in this document also may be useful to building owners, and government agencies; however these users should consult with a qualified engineer for interpretation or specific application of the document.

1.2 Basis and Scope

The evaluation procedure assumes that when an earthquake causes damage to a building, a competent engineer can assess the effects, at least partially, through visual inspection augmented by investigative tests, structural analysis, and knowledge of the building construction. By determining how the structural damage has changed structural properties, it is feasible to develop potential actions (performance restoration measures) that, if implemented, would restore the damaged building to a condition such that its future earthquake performance would be essentially equivalent to that of the building in its pre-event condition. The costs associated with these conceptual performance restoration measures quantify the loss associated with the earthquake damage.

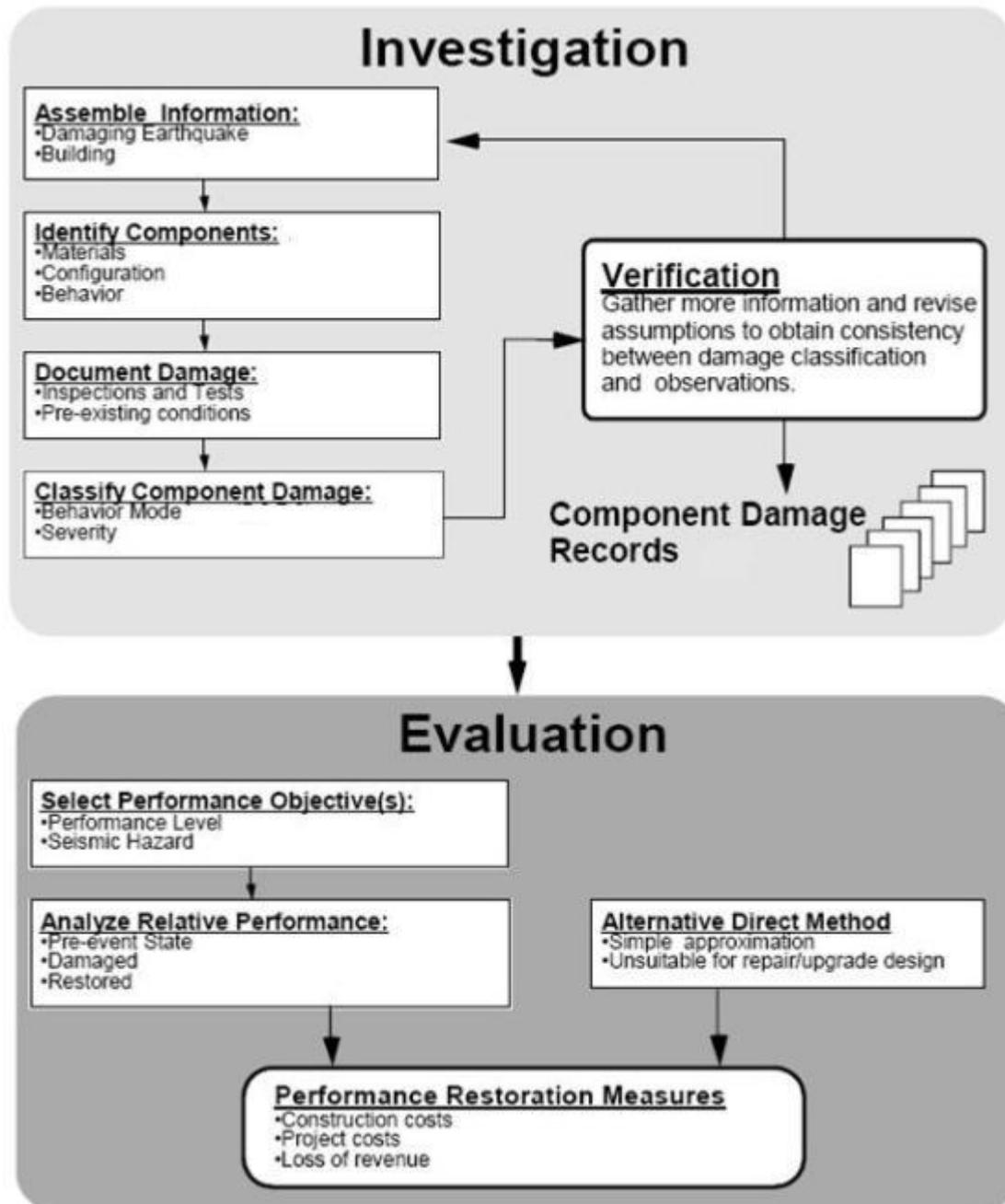
The theoretical basis of this guideline is based on different documents from FEMA and ATC namely FEMA 154, FEMA 273, FEMA 274, FEMA 306, FEMA 307, FEMA 308, FEMA 356, ATC 40 etc and the experience of damage assessment of the buildings after Kashmir earthquake in Pakistan.

There are four levels of damage assessment:

- Windshield: Overall scope of damage
- Rapid : Assessment sufficient for most buildings
- Detailed: Closer assessment of difficult or complex buildings
- Engineering : Consultant engaged by owner

This guideline covers the rapid and detailed assessment procedures. Process for windshield will be different as it is the overall damage assessment from air i.e. helicopter survey, the last one needs quantitative assessment of individual buildings.

2. DAMAGE ASSESSMENT FLOW-CHART



3. RAPID EVALUATION

Goal: Rapid Damage Assessment for Safety. Used to quickly post obviously unsafe and apparently safe structures, and to identify buildings requiring detailed evaluation

Situation:

- Usually a scarcity of skilled manpower available to conduct building by building inspections
- Designed to utilize the talents and experiences of professionals involved in building construction
- Once all buildings in a given area have been inspected and those that are apparently unsafe have been posted, the remaining structures, the so called gray-area buildings are left for a detailed assessment by a structural engineer

Rapid evaluation is done just after the earthquake to assess the safety of buildings to judge either people can enter the building or not. It can be done by visual inspection.

3.1 Visual Inspection

Visual inspection is perhaps the most useful test available in the assessment of earthquake damage to concrete and masonry walls. Generally, earthquake damage to concrete and masonry walls is visible on the exposed surface. Observable types of damage include cracks, spalls and delaminations, permanent lateral displacement, and buckling or fracture of reinforcement. Visual inspection can also be useful for estimating the drift experienced by the building. Visual inspection should always accompany other testing methods that are used. Findings from the visual inspections should be used as a basis for determining locations for conducting further testing. The observed damage should be documented on sketches. The patterns of damage can then be interpreted to assess the behavior of the wall during the earthquake.

3.1.1 Equipment Needed

The materials and equipment typically required for a visual inspection are a tape measure, a flashlight, a crack comparator, a pencil, and a sketchpad. A tape measure is used to measure the dimensions of the wall and, if necessary, to measure the lengths of the cracks. Tape measures that are readily available from a hardware store, with lengths of 20 to 50 feet, are sufficiently accurate for damage evaluation.

Flashlights are used to aid in lighting the areas to be inspected. In post-earthquake evaluations, electric power may not be completely available, so supplemental lighting should be supplied. In a visual inspection, the engineer uses a crack comparator or a tape measure to measure the width of cracks at representative locations. Two types of crack comparators are generally available: thin clear plastic cards, which have specified widths denoted on the card and small, hand-held magnifying lenses with a scale marked on the surface. Plastic card comparators have graduated lines to a minimum width of about 0.002 inches. Magnifying lens comparators are accurate to about 0.001 inch. The engineer uses a sketchpad to prepare a representation of the wall elevation, indicating the locations of

the cracks, spalling, or other damage. All significant features of the wall should be recorded, including the dimensions of openings, the finishes on the wall, and the presence of nonstructural elements that may affect the repairs. The sketch should be supplemented with photographs or video tape.

Detailed examination of the surface of a crack can be accomplished with a portable microscope, which allows for magnified viewing of the surface of the cracks. Portable microscopes are available with magnifications of 18- to 36-fold. An external light source is needed for viewing. A camera adapter may be available for photographic documentation.

3.1.2 Assessment Work

The initial steps in the visual observation of earthquake damage are to identify the location of the wall in the building and to determine the dimensions of the wall (height, length, and thickness). A tape measure is used for quantifying the overall dimensions of the wall. A sketch of the wall elevation should then be prepared. The sketch should include sufficient detail to depict the dimensions of the wall, it should be roughly to scale, and it should be marked with the wall location. Observable damage such as cracks, spalling, and exposed reinforcing bars should be indicated on the sketch. Sketches should be made in sufficient detail to indicate the approximate orientation and width of cracks. Crack width is measured using the crack comparator or tape measure at representative locations along significant cracks. Avoid holes and edge spalls when measuring crack widths. Crack widths typically do not change abruptly over the length of a crack. If the wall is accessible from both sides, the opposite side of the wall should be checked to evaluate whether the cracks extend through the thickness of the wall and to verify that the crack widths are consistent.

Photographs can be used to supplement the sketches. If the cracks are small, they may not show up in the photographs, except in extreme close-up shots. Paint, markers, or chalk can be used to highlight the location of cracks in photographs. However, photographs with highlighted crack should always be presented with a written disclaimer that the cracks have been highlighted and that the size of the cracks cannot be inferred from the photograph.

During a visual inspection, the engineer should carefully examine the wall for the type of damage and possible causes. Indications that the cracks or spalls may be recent or that the damage may have occurred prior to the earthquake should be noted. Visual observation of the nonstructural elements in the building can also be very useful in assessing the overall severity of the earthquake, the inter-story displacements experienced by the building, and the story accelerations. Full-height nonstructural items such as partitions and facades should be inspected for evidence of inter-story movement such as recent scrapes, cracked windows, or crushed wallboard.

3.1.3 Personal Qualification

Visual inspection of concrete and masonry walls should be performed by an engineer or trained technician. Engineers and technicians should have previous experience in identifying damage to concrete and masonry structures and should be familiar with the use of a tape measure and crack comparator. Engineers and technicians should also have sufficient training to be able to distinguish between recent damage and damage that may have been pre-existing. For this type of assessment, the person conducting the inspection should understand how the structure is designed and how earthquake, gravity, and other forces may have acted on the wall.

3.1.4 Limitations

The width of a crack can vary substantially along its length. Both the plastic card and the magnifying crack comparators can produce a reasonable estimate of the width of a crack. The magnifying comparators are generally more accurate when measuring small (<0.001 inches) crack widths. The

plastic cards can sometimes overestimate the crack width due to the lighting conditions. With either type of comparator, the crack width is only measured at representative locations to determine repair thresholds. The measurements should be used primarily to compare damage levels among walls. The crack comparators may not be necessary when the crack widths are to be measured in 1/16-inch increments. For wider cracks, a tape measure will provide sufficiently accurate values. Visual observation of concrete and masonry walls can generally identify most of the earthquake damage to those elements. In some cases, the presence of finishes on the walls can prevent an accurate assessment of the damage. Brittle finishes such as plaster can indicate damage that may not be present in the underlying substrate. Soft finishes such as partitions isolated from the structural walls can obscure minor amounts of damage.

3.2 Evaluation and Certification

The building needs to evaluate and certified. There can be three types of classification and certificates.

Posting Classification	Color	Description
INSPECTED	Green	No apparent hazard found, although repairs may be required. Original lateral load capacity not significantly decreased. No restriction on use or occupancy
LIMITED ENTRY	Yellow	Dangerous condition believed to be present. Entry by owner permitted only for emergency purposes and only at own risk. No usage on continuous basis. Entry by public not permitted. Possible major aftershock hazard
UNSAFE	Red	Extreme hazard, may collapse. Imminent danger of collapse from an aftershock. Unsafe for occupancy or entry, except by authorities.

3.2.1 Inspected

INSPECTED

NO RESTRICTIONS ON USE OR OCCUPANCY

This structure has been inspected (as indicated below) and no apparent structural hazard has been found. Report any unsafe conditions to local authorities; reinspection may be required.

Exterior Only
 Exterior and Interior

Facility Name and Address:

Date _____
Time _____

This facility was inspected under emergency conditions for:

(Jurisdiction)
on the date and time noted.

Inspector ID/Agency:

**Do Not Remove This Placard until
Authorized by Governing Authority.**

- Observed damage, if any, does not appear to pose a safety risk
- Vertical or lateral capacity not significantly decreased
- Repairs may be required
- Lawful entry, occupancy and use permitted

3.2.2 Limited Entry of Restricted Use

RESTRICTED USE

Caution: This structure has been inspected and found to be damaged as described below:

Entry, occupancy, and lawful use are restricted as indicated below:

Do not enter the following areas: _____

Brief entry allowed for access to contents: _____

Other restrictions: _____

Facility name and address:

Date _____
Time _____

(Caution: Aftershocks since inspection may increase damage and risk.)

This facility was inspected under emergency conditions for:

(Jurisdiction)

Inspector ID / Agency

**Do Not Remove, Alter, or Cover this Placard
until Authorized by Governing Authority**

- Some risk from damage in all or part of building
- Restricted
 - duration of occupancy
 - areas of occupancy
 - Usage
- Restrictions enforced by owner / manager

3.2.3 Unsafe

UNSAFE
DO NOT ENTER OR OCCUPY

Warning:
This structure has been seriously damaged and is unsafe. Do not enter. Entry may result in death or injury.

Comments: _____

Facility Name and Address:

Date _____
Time _____

This facility was inspected under emergency conditions for:

(Jurisdiction)
on the date and time noted.

Inspector ID/Agency:

**Do Not Remove This Placard until
Authorized by Governing Authority.**

- Falling, collapse, or other hazard
- Does not necessarily indicate that demolition is required
- Owner must mitigate hazards to satisfaction of jurisdiction to gain entry

4. DETAIL EVALUATION

4.1 Understanding the Characteristics of Damaging Earthquake

During the evaluation of damage to concrete or masonry wall buildings, information on the characteristics of the damaging earthquake can lead to valuable insight on the performance characteristics of the structure. For example, if the ground motion caused by the earthquake can be estimated quantitatively, the analysis techniques can provide an estimate of the resulting maximum displacement of the structure. This displacement, in conjunction with the theoretical capacity curve, indicates an expected level of component damage. If the observed component damage is similar to that predicted, the validity of the theoretical model is verified in an approximate manner. If the damage differs, informed adjustments can be made to the model.

4.2 Review of Existing Building Data

The data collection process begins with the acquisition of documents describing the pertinent conditions of the building. Review of construction drawings simplifies field work and leads to a more complete understanding of the building. Original architectural and structural construction drawings are central to an effective and efficient evaluation of damage. Potential sources of these and other documents include the current and previous building owners, building departments, and the original architects or engineers. Drawings may also be available from architects or engineers who have performed prior evaluations for the building. In addition to construction drawings, it is helpful to assemble the following documents if possible:

- Site seismicity/geotechnical reports
- Structural calculations
- Construction specifications
- As Built Drawings
- Foundation reports
- Prior building assessments

Review of the existing building information serves several purposes. If reviewed before field investigations, the information facilitates the analytical identification of structural components. This preliminary analysis also helps to guide the field investigation to components that are likely to be damaged. Existing information can also help to distinguish between damage caused by the earthquake and pre-existing damage. Finally, the scope of the field inspection and testing program depends on the accuracy and availability of existing structural information. For example, if structural drawings reliably detail the size and placement of reinforcing, expensive and intrusive tests to verify conditions in critical locations may be unnecessary.

4.3 Assessing the Consequences of the Damaging Earthquake

Methods for inspecting and testing concrete and masonry wall buildings for earthquake damage fall into two general categories, nondestructive and intrusive. Nondestructive techniques do not require any removal of the integral portions of the components. In some cases, however, it may be necessary to remove finishes in order to conduct the procedure. In contrast, intrusive techniques involve extraction of structural materials for the purpose of testing or for access to allow inspection of portions of a component.

4.4 Assessing Pre-existing Conditions

Interpretation of the findings of damage observations requires care and diligence. When evaluating damage to a concrete or masonry wall, an engineer should consider all possible causes in an effort to distinguish between that attributable to the damaging earthquake and that which occurred earlier (pre-existing conditions).

Since the evaluation of earthquake damaged buildings is typically conducted within weeks or months of the event, cracking and spalling caused by earthquakes is normally relatively recent damage. Cracks associated with drying shrinkage or a previous earthquake, on the other hand, would be relatively old. General guidance for assessing the relative age of cracks based on visual observations is as follows.

Recent cracks typically have the following characteristics:

- Small, loose edge spalls
- Light, uniform color of concrete or mortar within crack
- Sharp, uneroded edges
- Little or no evidence of carbonation

Older cracks typically have the following characteristics:

- Paint or soot inside crack
- Water, corrosion, or other stains seeping from crack
- Previous, undisturbed patches over crack
- Rounded, eroded edges
- Deep carbonation

Evaluating the significance of damage requires an understanding of the structural behavior of the wall during the earthquake. The evaluating engineer must consider the implications of the observations with respect to the overall behavior of the building and the results of analytical calculations. The behavior must be correlated with the damage. If the observed damage is not reasonably consistent with the overall seismic behavior of the structure, the crack may have been caused by an action other than the earthquake.

4.5 Survey the Building from Outside

- Begin the survey by walking around the exterior of the building
- Try to determine the structural system
- Examine the structure for vertical discontinuities
- Examine the structure for irregular configuration in plan
- Look for cracking of exterior walls, glass frames etc., which are symptoms of excessive drift
- Examine non-structural elements
- Look for new fractures in the foundation or exposed lower wall of buildings
- Different Inspection and test required to conduct.

4.6 Examine the site for Geotechnical Hazards

- Examine the site for fissures, bulged ground, and vertical movements
- In hillside areas, examine the area for landslide displacement and debris encroaching onto the site
- Since geotechnical hazards can extend in area to include several or more buildings, undamaged buildings in an unstable area may be posted limited entry or unsafe

4.7 Inspect the structural system from inside the building

- Before entering the building, look for falling hazards and consider the danger of collapse
- Enter building
- Check the structural system
- Look in stairwells, basements, mechanical rooms etc. to view the structural system
- Examine the vertical load carrying system
- Examine the lateral load carrying system
- Check the different types of buildings using checklist

4.8 Conduct Test

4.8.1 Sounding Test

Description

Tapping on a wall with a dense object, such as a hammer, and listening to the vibrations emitted from the wall can be useful for identifying voids or delaminations in concrete walls. The sound produced from a solid wall will be different from that from a wall with voids or delaminations close to the surface. In concrete block masonry walls, sounding can be used to verify that the cells in the blocks have been grouted.

Equipment

The typical equipment required for sounding is a hammer. However, any hard, dense object can be used.

Conducting Test

In areas where the visual observations indicate that the wall may have delaminations, the wall can be sounded by tapping with a hammer. Delaminations and spalls will generally produce a hollow sound when compared with solid material. The wall should be tapped several times in the suspect area and away from the suspect area, and the sounds compared. It is important to test an area that is undamaged, and of the same material and thickness to use as a baseline comparison. For a valid comparison, the force exerted by the tapping should be similar for both the suspect and baseline areas. In reinforced masonry construction, sounding can be used to assess whether the cells in the wall have been grouted. Near the ends of a block, the unit is solid for the full thickness of the wall. For most of the length of the block, it is relatively thin at the faces. If the sound near the end of the block is substantially different than at the middle of the cell, the cell is probably not grouted.

Personal Qualification

Sounding of concrete and masonry walls should be performed by an engineer or trained technician. Engineers and technicians should have previous experience in identifying damage to concrete and masonry structures. Engineers and technicians should also be able to distinguish between sounds emitted from a hammer strike. Prior experience is necessary for proper interpretation of results.

Reporting Requirements

The personnel conducting the tests should provide sketches of the wall indicating the location of the tests and the findings. The sketch should include the following information:

- Mark the location of the test on either a floor plan or wall elevation.
- Report the results of the test, indicating the extent of delamination.
- Report the date of the test.
- List the responsible engineer overseeing the test and the name of the company conducting the test.

Limitations

The properties of the wall can influence the usefulness of sounding. The geometry of the wall and the thickness of the wall will affect the results. Sounding is best used away from the perimeter of the wall and on a wall of uniform thickness. The accuracy of information from sounding with a hammer also depends on the skill of the engineer or technician performing the test and on the depth of damage within the thickness of the wall. Delaminations up to the depth of the cover for the reinforcing bars (usually about 1 to 2 inches) can usually be detected. Detection of deeper spalls or delamination requires the use of other NDE techniques. Sounding cannot determine the depth of the spall or delamination.

Tapping on a loose section of material can cause the piece to become dislodged and fall. Avoid sounding overhead. A ladder, scaffold, or other lift device should be used to reach higher elevations of a wall.

4.8.2 Rebound Hammer Test

Description

A rebound hammer provides a method for assessing the in-situ compressive strength of concrete. In this test, a calibrated hammer impact is applied to the surface of the concrete. The amount of rebound of the hammer is measured and correlated with the manufacturer's data to estimate the strength of the concrete. The method has also been used to evaluate the strength of masonry.

Equipment

A calibrated rebound hammer is a single piece of equipment that is hand operated

Execution

The person operating the equipment places the impact plunger of the hammer against the concrete and then presses the hammer until the hammer releases. The operator then records the value on the scale of the hammer. Typically three or more tests are conducted at a location. If the values from the tests

are consistent, record the average value. If the values vary significantly, additional readings should be taken until a consistent pattern of results is obtained.

Since the test is relatively rapid, a number of test locations can be chosen for each wall. The values from the tests are converted into compressive strength using tables prepared by the manufacturer of the rebound hammer.

Personal Qualification

A technician with minimal training can operate the rebound hammer. An engineer experienced with rebound hammer data should be available to supervise to verify that any anomalous values can be explained.

Reporting Requirements

The personnel conducting the tests should provide sketches of the wall, indicating the location of the tests and the findings. The sketch should include the following information:

- Mark the location of the test marked on either a floor plan or wall elevation.
- Record the number of tests conducted at a given location.
- Report either the average of actual readings or the average values converted into compressive strength along with the method used to convert the values into compressive strength.
- Report the type of rebound hammer used along with the date of last calibration.
- Record the date of the test.
- List the responsible engineer overseeing the test and the name of the company conducting the test.

Limitations

The rebound hammer does not give a precise value of compressive strength, but rather an estimate of strength that can be used for comparison. Frequent calibration of the unit is required (ACI, 1994). Although manufacturers' tables can be used to estimate the concrete strength, better estimates can be obtained by removing core samples at selected locations where the rebound testing has been performed. The core samples are then subjected to compression tests. The rebound values from other areas can be compared with the rebound values that correspond to the measured core compressive strength.

The results of the rebound hammer tests are sensitive to the quality of the concrete on the outer several inches of the wall. More reproducible results can be obtained from formed surfaces rather than from finished surfaces. Surface moisture and roughness can also affect the readings. The impact from the rebound hammer can produce a slight dimple in the surface of the wall. Do not take more than one reading at the same spot, since the first impact can affect the surface, and thus affect the results of a subsequent test.

When using the rebound hammer on masonry, the hammer should be placed at the center of the masonry unit. The values of the tests on masonry reflect the strength of the masonry unit and the mortar. This method is only useful in assessing the strength of the outer wythe of a multi-wythe wall.

4.8.3 Rebar Detection Test

Description

Covermeter is the general term for a rebar detector used to determine the location and size of reinforcing steel in a concrete or masonry wall. The basic principle of most rebar detectors is the interaction between the reinforcing bar and a low frequency magnetic field. If used properly, many types of rebar detectors can also identify the amount of cover for the bar and/or the size of the bar. Rebar detection is useful for verifying the construction of the wall, if drawings are available, and in preparing as-built data if no previous construction information is available.

Equipment

Several types and brands of rebar detectors are commercially available. The two general classes are those based on the principle of magnetic reluctance and those based on the principle of eddy. The various models can have a variety of features including analog or digital readout, audible signal, onehanded operation, and readings for reinforcing bars and prestressing tendons. Some models can store the data on floppy disks to be imported into computer programs for plotting results.

Conducting Test

The unit is held away from metallic objects and calibrated to zero reading. After calibration, the unit is placed against the surface of the wall. The orientation of the probe should be in the direction of the rebar that is being detected. The probe is slid slowly along the wall, perpendicular to the orientation of the probe, until an audible or visual spike in the readout is encountered.

The probe is passed back and forth over the region of the spike to find the location of the maximum reading, which should correspond to the location of the rebar. This location is then marked on the wall. The procedure is repeated for the perpendicular direction of reinforcing.

If size of the bar is known, the covermeter readout can be used to determine the depth of the reinforcing bar. If the depth of the bar is known, the readout can be used to determine the size of the bar. If neither quantity is known, most rebar detectors can be used to determine both the size and the depth using a spacer technique.

The process involves recording the peak reading at a bar and then introducing a spacer of known thickness between the probe and the surface of the wall. A second reading is then taken. The two readings are compared to estimate the bar size and depth. Intrusive testing can be used to help interpret the data from the detector readings. Selective removal of portions of the wall can be performed to expose the reinforcing bars. The rebar detector can be used adjacent to the area of removal to verify the accuracy of the readings.

Personnel Qualifications

The personnel operating the equipment should be trained and experienced with the use of the particular model of covermeter being used and should understand the limitations of the unit.

Reporting Requirements

The personnel conducting the tests should provide a sketch of the wall indicating the location of the testing and the findings. The sketch should include the following information:

- Mark the locations of the test on either a floor plan or wall elevation.

- Report the results of the test, including bar size and spacing and whether the size was verified.
- List the type of rebar detector used.
- Report the date of the test.
- List the responsible engineer overseeing the test and the name of the company conducting the test.

Limitations

Pulse-velocity measurements require access to both sides of the wall. The wall surfaces need to be relatively smooth. Rough areas can be ground smooth to improve the acoustic coupling. Couplant must be used to fill the air space between the transducer and the surface of the wall. If air voids exist between the transducer and the surface, the travel time of the pulse will increase, causing incorrect readings.

Some couplant materials can stain the wall surface. Non-staining gels are available, but should be checked in an inconspicuous area to verify that it will not disturb the appearance.

Embedded reinforcing bars, oriented in the direction of travel of the pulse, can affect the results, since the ultrasonic pulses travel through steel at a faster rate than will significantly affect the results. The moisture content of the concrete also has a slight effect (up to about 2 percent) on the pulse velocity.

Pulse-velocity measurements can detect the presence of voids or discontinuities within a wall; however, these measurements cannot determine the depth of the voids.

4.8.4 In-Situ Testing In-Place Shear

Description

The shear strength of unreinforced masonry construction depends largely on the strength of the mortar used in the wall. An in-place shear test is the preferred method for determining the strength of existing mortar. The results of these tests are used to determine the shear strength of the wall.

Equipment

- Chisels and grinders are needed to remove the bricks and mortar adjacent to the test area.
- A hydraulic ram, calibrated and capable of displaying the applied load.
- A dial gauge, calibrated to 0.001 inch.

Execution

Prepare the test location by removing the brick, including the mortar, on one side of the brick to be tested. The head joint on the opposite side of the brick to be tested is also removed. Care must be exercised so that the mortar joint above or below the brick to be tested is not damaged.

The hydraulic ram is inserted in the space where the brick was removed. A steel loading block is placed between the ram and the brick to be tested so that the ram will distribute its load over the end face of the brick. The dial gauge can also be inserted in the space.

The brick is then loaded with the ram until the first indication of cracking or movement of the brick. The ram force and associated deflection on the dial gauge are recorded to develop a force-deflection

plot on which the first cracking or movement should be indicated. A dial gauge can be used to calculate a rough estimate of shear stiffness.

Inspect the collar joint and estimate the percentage of the collar joint that was effective in resisting the force from the ram. The brick that was removed should then be replaced and the joints repointed.

Personnel Qualifications

The technician conducting this test should have previous experience with the technique and should be familiar with the operation of the equipment. Having a second technician at the site is useful for recording the data and watching for the first indication of cracking or movement. The structural engineer or designee should choose test locations that provide a representative sampling of conditions.

Reporting Results

The personnel conducting the tests should provide a written report of the findings to the evaluating engineer. The results for the in-place shear tests should contain, at a minimum, the following information for each test location:

- Describe test location or give the identification number provided by the engineer.
- Specify the length and width of the brick that was tested, and its cross-sectional area.
- Give the maximum mortar strength value measured during the test, in terms of force and stress.
- Estimate the effective area of the bond between the brick and the grout at the collar joint.
- Record the deflection of the brick at the point of peak applied force.
- Record the date of the test.
- List the responsible engineer overseeing the test and the name of the company conducting the test.

Limitations

This test procedure is only capable of measuring the shear strength of the mortar in the outer wythe of a multi-wythe wall. The engineer should verify that the exterior wythe being tested is a part of the structural wall, by checking for the presence of header courses. This test should not be conducted on veneer wythes.

Test values from exterior wythes may produce lower values when compared with tests conducted on inner wythes. The difference can be due to weathering of the mortar on the exterior wythes. The exterior brick may also have a reduced depth of mortar for aesthetic purposes.

The test results can only be qualitatively adjusted to account for the presence of mortar in the collar joints. If mortar is present in the collar joint, the engineer or technician conducting the test is not able to discern how much of that mortar actually resisted the force from the ram.

The personnel conducting the tests must carefully watch the brick during the test to accurately determine the ram force at which first cracking or movement occurs. First cracking or movement indicates the maximum force, and thus the maximum shear strength. If this peak is missed, the values obtained will be based only on the sliding friction contribution of the mortar, which will be less than the bond strength contribution.

4.9 Safety Evaluation

The damage evaluation procedures in this document are performance-based; that is, they assess the acceptability of the structural system (and the significance of changes in the structural system) on the basis of the degree to which the structure achieves one or more performance levels for the hazard posed by one or more hypothetical future earthquakes. A performance level typically is defined by a particular damage state for a building. The performance levels defined in FEMA 273, in order of decreasing amounts of damage, are collapse prevention, life safety, and immediate occupancy. Hazards associated with future hypothetical earthquakes are usually defined in terms of ground shaking intensity with a certain likelihood of being exceeded over a defined time period or in terms of a characteristic earthquake likely to occur on a given fault. The combination of a performance level and a hazard defines a performance objective. For example, a common performance objective for a building is that it maintain life safety when subjected to ground motion with a ten-percent chance of exceedance in fifty years.

The damage evaluation begins with the selection of an appropriate performance objective. The performance objective serves as a benchmark for measuring the difference between the anticipated performance of the building in its damaged and pre-event states, that is, relative performance analysis. The absolute performance acceptability of the damaged or pre-event building does not affect the quantification of loss. The quantification of performance loss is affected by the choice of performance objective, as illustrated in the following paragraph. Consequently, the selection of objectives is a matter of policy that depends on the occupancy and use of the facility. Guidance may be found in ATC-40, FEMA 273/274, and FEMA 308. It is important to note that the damage evaluation procedure can be used to investigate changes in performance characteristics for either single or multiple performance objectives. For example, a hospital might be expected to remain functional (immediate occupancy) after a rare event. For a very rare event, the life safety performance level might be acceptable. The damage evaluation procedure may be used with either or both performance objectives, and the loss associated with the damage may be different for the two objectives.

4.10 Identification of Damage Levels

After evaluation of individual components, the hospital building is classified in one of the following five categories:

Insignificant (Damage Grade 1): Damage does not significantly affect structural properties in spite of a minor loss of stiffness. Restoration measures are cosmetic unless the performance objective requires strict limits on nonstructural component damage in future events.

Slight (Damage Grade 2): Damage has a small effect on structural properties. Relatively minor structural restoration measures are required for restoration for most components and behavior modes.

Moderate (Damage Grade 3): Damage has an intermediate effect on structural properties. The scope of restoration measures depends on the component type and behavior mode. Measures may be relatively major in some cases.

Heavy (Damage Grade 4): Damage has a major effect on structural properties. The scope of restoration measures is generally extensive. Replacement or enhancement of some components may be required.

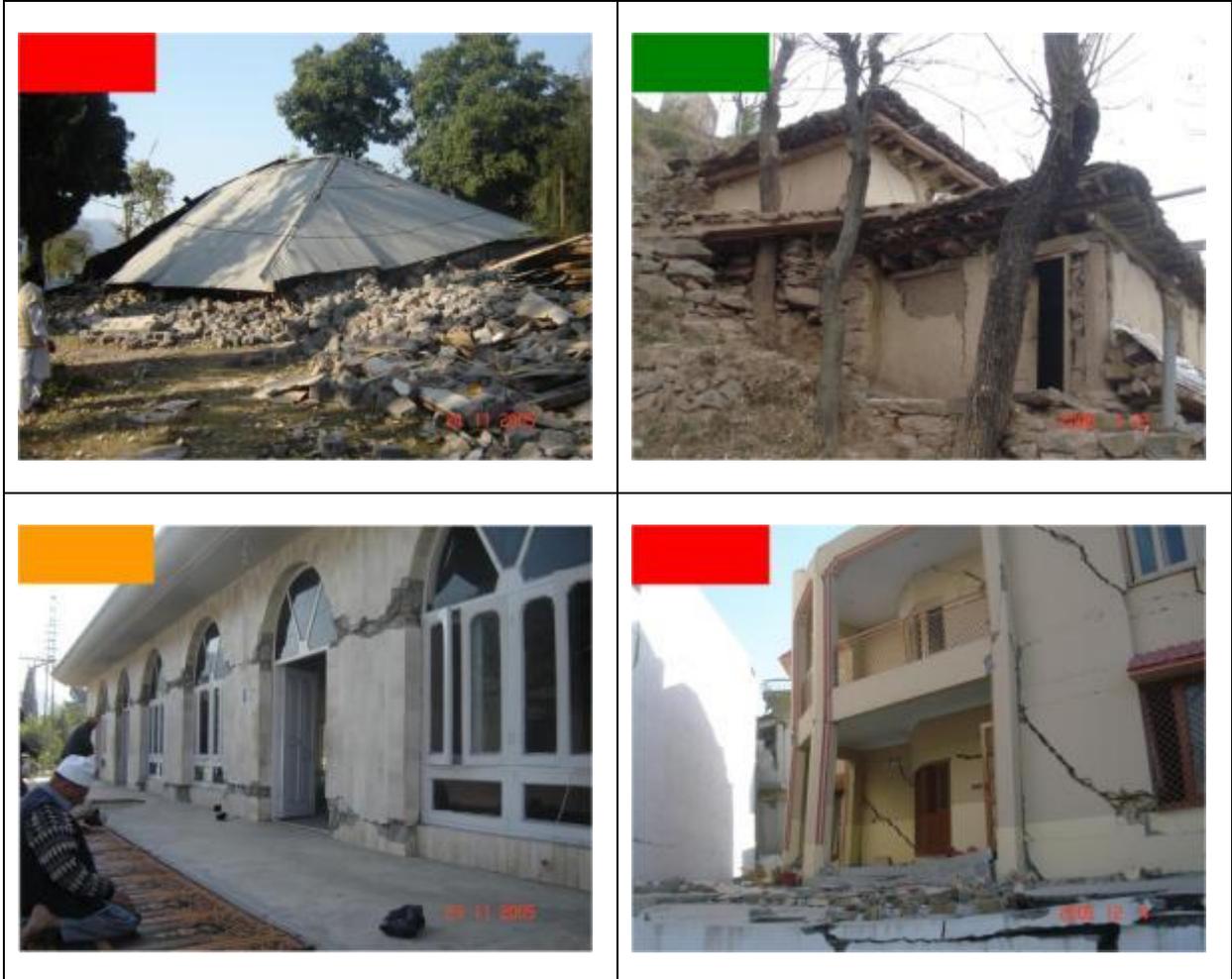
Extreme (Damage Grade 5): Damage has reduced structural performance to unreliable levels. The scope of restoration measures generally requires replacement or enhancement of components.

5. REFERENCES

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ANNEXES

Examples of Rapid Evaluation







Examples of Detailed Evaluated Buildings



